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RESEARCH ARTICLE

Animal welfare efforts and farm economic outcomes: Evidence from Swedish beef production

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Abstract
We estimate the relationship between farm animal welfare (FAW) efforts taken by beef farmers and the economic performance of beef farms by using farm accounting data from the Swedish Farm Economic Survey matched with survey data on farm management practices. To this end, we perform a two-step analysis. First, an item response theory (IRT) model estimates the latent FAW effort on farms. FAW effort likely depends on a host of complementary FAW-improving strategies, and the IRT model combines the considered strategies into a unidimensional scale. We take this to represent on-farm FAW effort. Second, we use instrumental variable regressions to estimate the relationship between FAW effort and multiple measures of farm economic performance. We find that higher FAW effort scores have no effect on margins and costs. However, higher FAW effort scores are associated with lower farm sales. Findings suggest that policies (such as targeted label for high FAW) that increase farm revenue as well as incentivize the uptake of FAW-improvement practices may be able to compensate farmers for their FAW effort.

Keywords: animal welfare; beef production; item response theory (IRT); Sweden

JEL Classifications: Q18; Q10

Introduction

Consumers, citizens, and policy makers are concerned about the welfare of production animals (farm animal welfare; FAW) and about the food industry's compliance with ethical standards of animal-based food systems (Lusk 2011; Johansson-Stenman 2018). In response, regulatory authorities and governments, especially in North America and EU, have made provisions that intend to improve FAW (1) to ensure a certain level of health and well-being for animals on the farm and (2) to reduce the negative externalities associated with poor FAW (Malone and Lusk 2016). However, improving FAW requires efforts taken by producers, which often implies higher costs of production. The relationship between such efforts taken to improve FAW and the economic performance of farms is contested as farmers suggest that the demand for greater FAW efforts can make them uncompetitive and force them out of the industry (Balzani and Hanlon 2020). Thus, this study contributes to this debate by estimating the relationship between FAW efforts and economic performance, using beef farms in Sweden as an empirical example. In doing so, this study provides a much-needed empirical test of the farmers' claim regarding the costliness of FAW efforts.

Several studies contribute to this debate and have found positive (e.g., Alvasen et al. 2017; Henningsen et al. 2018) as well as negative relationships (e.g., Ahmed et al. 2021; Ahmed et al. 2020) between FAW efforts and on-farm economic performance. Previous literature has used expert assessments (Jensen et al. 2012), simulations (Alvasen et al. 2017; Ahmed et al. 2020; Ahmed et al. 2021), and primary data from commercial farms (Lawson et al. 2004; Barnes et al. 2011; Stott et al. 2012; Henningsen et al. 2018) to estimate the relationship between FAW and economic performance. Several studies have used animal health indicators (outcome-based measures) to proxy observed FAW or FAW efforts undertaken at the farm (e.g., Lawson et al. 2004; Barnes et al. 2011), while Henningsen et al. (2018) used compliance with FAW regulations as an indicator of FAW. Similarly, studies that simulate the relationship between FAW-improving measures and economic performance typically use single FAW-improving strategies, e.g., housing allowance, forage-to-concentrate ratios, etc., in isolation (Ahmed et al. 2020).

However, FAW efforts made by farmers typically go beyond one or two strategies or measures and can be considered a combination of complementary farm management strategies. Therefore, we develop a composite FAW effort measure that simultaneously takes into account multiple strategies adopted by farms to improve FAW. The composite measure is used to empirically investigate the impact of such efforts on farm economic performance. We focus on beef farms in Sweden, given the lack of evidence in the literature regarding the economic consequences of FAW efforts in these types of farms. We use the farm-level accounting data from the Farm Economic Survey (FES) to obtain measures of farm economic performance and match them with our own survey instrument from which we can estimate FAW effort taken by the beef farmers enrolled in FES. We first use the item response theory (IRT) 1-parameter model (Rasch 1960; Rasch 1966; Hambleton and Swaminathan 1985) to measure latent FAW effort on farms. IRT models are used in several social science disciplines because they consistently map multiple evaluation criteria onto a unidimensional measurement scale (Chen and Thissen 1997; Abdul-Salam and Phimister 2017; Yount et al. 2019; Dohoo and Emanuelson 2021).

Second, we integrate the theory of use and nonuse values (in line with McInerney (2004), Lagerkvist et al. (2011), Hansson and Lagerkvist (2016), Hansson et al. (2018) and Hansson et al. (2020)) in our latent instrumental variable model (see e.g., Ebbes et al. 2009; Zhang et al. 2009; Rutz et al. 2012) to explain the variability in FAW effort and to identify the relationship between FAW effort and farm's economic performance. Nonuse values represent a farmer's motivation to adopt FAW-improving measures beyond the motive of profit and productivity. Indeed, it is well known that farmers may choose to take measures to improve FAW without being forced to do so by legislation or without expecting these measures to add to the financial profit of the farms, simply because they believe in providing the animals in their care a decent life (Lagerkvist et al. 2011; Hansson and Lagerkvist 2016). Thus, based on the definition of nonuse values in FAW as elaborated by McInerney (2004), Lagerkvist et al. (2011), Hansson and Lagerkvist (2016), Hansson et al. (2018) and Hansson et al. (2020), our identifying assumption is that nonuse values only affect economic outcomes through their impact on the uptake of FAW efforts and are uncorrelated with unobservables that directly affect farm economic performance.

The study contributes to the literature in several ways. Although the literature has made use of latent-class models to estimate the adoption of FAW practices (e.g., Owusu-Sekyere et al. 2022), to our knowledge, this is the first study that uses IRT models to develop a composite FAW effort measure that simultaneously considers complementary FAW-improving measures and maps them onto a unidimensional scale. Such a framework can be widely used to assess FAW efforts undertaken on the farm for several species and contexts. A second novelty of this study is the use of nonuse motivational constructs related to farmer FAW efforts as instrumental variables. This empirical strategy allows us to: (a) overcome the simultaneity and endogeneity bias that can occur while estimating the relationship between FAW effort and farm economic performance and (b) extend the modeling approach used in Owusu-Sekyere et al. (2022) to include farm economic outcomes beyond the adoption model for FAW practices. Lastly, this case study uses data from beef cattle fattening and breeding operations, which have not received as much attention as some of the other species in the empirical literature on FAW and economic performance. For example, Henningsen et al. (2018) focus on pig production, while Barnes et al. (2011) and Schulte et al. (2018) focus on dairy production.

Results from the IRT model indicate that the set of FAW-improving measures function reasonably well as a scale for measuring a farmer's FAW effort. Our scale can credibly distinguish between farmers with high effort from those with average or lower than average effort. While we find statistically insignificant effects of high FAW effort scores on our measures of contribution margins and costs, results indicate that higher FAW scores are associated with lower farm sales. Results imply that FAW efforts taken on the farm can have consequences on revenue and therefore farm advice and policy schemes should focus on measures that reduce the trade-off between revenue maximization and higher FAW provisions to ensure the economic viability of farms and preservation of FAW at the same time.

Materials and methods

Conceptual considerations

On one hand, the actions taken in the production process through the management efforts of farmers (e.g., grouping of animals, disease and parasite control activities, housing allowances, and cleaning etc.) govern the level of FAW on a farm (Henningsen et al. 2018). These managerial activities consist of a wide range of complementary observable as well as unobservable strategies (e.g., cow–calf contact periods and pasture allowance) and behavioral traits that define FAW effort. Therefore, to take into account these complementary FAW-improving strategies and capture the multidimensional nature of FAW effort, we conceptualize it as a latent trait, such that the observable FAW-improving strategies are mapped onto a unidimensional scale to consistently measure FAW effort taken on a farm.

FAW effort may have important effects on production decisions and thus on farm economic outcomes. First, greater FAW effort may increase production costs due to increased labor needs and/or increased use of other production factors used to achieve a specific level of FAW effort. Second, greater FAW effort may increase the yield by increasing efficiency and productivity (e.g., higher growth rates and fertility of animals). Furthermore, the marginal benefit of FAW efforts may depend on the initial level of FAW. If the level of FAW is already high, then additional efforts may yield only little in terms of productivity or profitability (diminishing marginal returns), while small FAW efforts taken on farms with poor

FAW may provide higher marginal returns (McInerney 2004; Henningsen et al. 2018). This theoretical relationship suggests synergistic effects between FAW effort and economic performance, which could be positive or negative. In addition, FAW efforts may also be implemented on a farm due to nonpecuniary or nonuse value concerns. Indeed, nonuse values, such as those discussed in McInerney (2004) and Lagerkvist et al. (2011), may play an important role in the uptake of FAW effort. Farmers may trade-off economic efficiency for higher levels of FAW if nonpecuniary factors are relevant (Hansson et al. 2020; Adamie and Hansson, 2022).

Thus, the economic performance of a farm is hypothesized to be affected by FAW effort through the production decisions. Economic performance is measured by contribution margins, revenue, and costs, each normalized by farm size, to illustrate the multidimensional channels (i.e., revenue and costs) through which FAW effort is associated with economic performance. The conceptual framework is similar to McInerney (2004) and Henningsen et al. (2018) and provides a basis for thinking about and developing an empirical strategy to estimate the relationship between FAW effort and economic performance.

Data

Data used in this study were obtained from a sample of farms in Sweden that owned 10 or more beef cattle in 2019. A sample of 325 farms, which were present in FES as well as the CDB database (which is the central register for bovine animals in Sweden), were chosen and sent the request to respond to our survey. We received 140 responses (response rate of ~43%). The respondents were given the option to complete the survey on paper as well as online. We received about half of the surveys through the online portal while the other half was on paper. These 140 responses were matched with their records with the latest available FES from 2017, using the unique farm identification code provided in CDB, FES, and our survey instrument. FES contains detailed accounting data on costs of production and revenues generated by a sample of farms in Sweden and functions as Sweden's input to the farm accounting data network (FADN) in the European Union. In this study, we focus on the farms engaged in beef production and used a final set of 115 observations for the analysis as missing values were removed from the data. Thus, the effective response rate in relation to the survey was ~36%. To ensure confidentiality and respondent anonymity to the researchers, the Swedish Board of Agriculture, without any self-interest in the study, collected the data on behalf of the research group, which only received anonymous data. Data collection took place from late March to the end of August 2020.

Our focus is to estimate the relationship between FAW effort and farm economic performance. The main dependent variables that capture different dimensions of economic performance are *Contribution Margin Ratio (CMR)*, *Sales per Livestock Unit (LU),* and *Costs per LU* from the FES data. *CMR* was calculated by taking the difference between the revenue generated by the sale of beef cattle and feed, veterinary, and animal husbandry costs (contribution margin), divided by the revenue from beef sales (Table A1). This division of contribution margin by revenue was done in order to correct for farm size and to avoid inadvertently measuring farm size instead of economic outcome (following Hansson et al. (2018)). Furthermore, beef-related revenues and costs associated with beef production (e.g., veterinary, animal husbandry, and feed costs) were normalized by livestock units to obtain *Sales per LU* and *Costs per LU* measures (Table A1).

Table A1 provides data description while Table 1 provides summary statistics. The mean *CMR* is 83.8% in our sample, while the average *Sales per LU* and *Costs per LU* are 5,895 SEK (Swedish Kronor) and 770 SEK, respectively. Mean *Feed Costs*, *Husbandry Costs,* and *Veterinary Costs* amounted 120,732 SEK, 7,819 SEK, and 8,119

Table 1. Summary Statistics

	Mean	SD	Min	Max
Revenues and Costs				
Contribution Margin Ratio (CMR)	83.8	26.75	−69.3	100
Sales per LU (SEK)	5,895.0	3,533.8	0	18,070
Cost per LU (SEK)	770.0	1,083.1	0	6,156.1
Beef Sales (SEK)	882,594	1,173,717	0	6,328,081
Feed Costs (SEK)	120,732	298,572	0	2,055,410
Husbandry Costs (SEK)	7,819	23,459	0	123,408
Veterinary Costs (SEK)	8,119	17,238	0	177,818
Farm/Farmer Characteristics				
Herd Size (LU)	120.45	125.31	2	699
Proportion of Income (%)	41.0	27.22	0	100
Fattening Unit (Yes/No)	0.43	–	0	1
Breeding Unit (Yes/No)	0.28	–	0	1
Mixed Unit (Yes/No)	0.29	–	0	1
Experience (Years)	26.6	13.9	4	62
FAW-Improving Measures				
Animals Grouped (Yes/No)	0.84	–	0	1
Batchwise Breeding (Yes/No)	0.26	–	0	1
Parasite Control (Yes/No)	0.62	–	0	1
Animal Health Group (Yes/No)	0.58	–	0	1
Precision Tech (Yes/No)	0.15	–	0	1

$N = 115$

SEK, respectively. The minimum value of zero for the cost items may reflect that either the animals are pasture raised or their feed is composed of raw materials produced from other farm operations (and does not show up in the cost items). Similarly, a zero value for *Sales per LU* may mean that the farm did not make any sales during the sample period. Indeed, in Sweden, there may be breeding plus fattening beef farms of small to moderate size where the animals are kept longer than a year before being sold off in the market. Mean *Beef Sales* amounted to 882,594 SEK.[1]

[1]Given the response rate of 43%, one concern could be that farmers that are more interested in farm animal welfare self-select into filing out the survey. Using pairwise t-tests, we compared the averages of sales and costs among FES farmers that filled out our survey vs those that did not. We found no statistically significant differences across costs. We also found that the average sales were lower among nonrespondents (statistically significant at 5% level of significance), alleviating the concern that more farm animal welfare focused farmers adopted the survey. These results combined with the fact that FES covers a representative sample of beef producers in Sweden suggest that our data is representative of the population of beef farmers in Sweden.

Table 2. Measurement Items of Paternalistic Altruism

	Statement	Mean (SD)
Measurement Item 1	To make it possible for consumers to demand my production also in the long run.	1.64 (0.77)
Measurement Item 2	To feel proud that the way I keep my animals is acknowledged by the industry, market, or consumers.	1.81 (0.42)
Measurement Item 3	To contribute to consumers being offered high-quality food products	1.80 (0.41)

Each item is measured on a Likert scale from −2 to 2, the range indicating strong disagreement to strong agreement with the statement. The scale reliability coefficient or Cronbach's α for the entire scale is 0.85.

The questionnaire documents information on the adoption of FAW-improving measures that are relevant to defining farm-level effort, which can be used in a latent class measurement model to estimate FAW effort, which is our main dependent variable. These FAW-improving measures include *Animals Grouped*, *Batchwise Rearing*, *Parasite Control*, *Animal Health Group*, and *Precision Tech*. Indeed, previous research shows that these measures positively affect animal health and FAW (Alvåsen et al. 2017; Vudriko et al. 2018; Buller et al. 2020). Grouping of animals according to gender and/or age (*Animals Grouped*) is the most widely adopted FAW-improvement measure with 84% of the sample adopting *Animals Grouped* while adoption of precision technology (*Precision Tech*) for individual monitoring of animals is the least adopted in our sample with 15% of the sample adopting *Precision Tech* (Table 1). 26%, 62%, and 58% of the sample adopts *Batchwise Rearing*, *Parasite Control*, and inclusion in an *Animal Health Group*.[2] It is worth noting that these measures are not related to the FAW regulatory requirements and therefore represent farmer's choice of investing in FAW improvement beyond statutory requirements.

Data on farm and farmer characteristics were also drawn from the questionnaire (Table 1). The mean beef cattle herd size in our sample was 120.45 livestock units at the farm with the average proportion of income drawn from the beef farm being 41%. Our sample consisted of 43% specialized cattle fattening units, while 28% were specialized breeding units, and 29% did breeding and fattening. Average experience of managing a beef farm in our sample was 26.6 years.

Our questionnaire also included a use and nonuse motivational scale based on Hansson and Lagerkvist (2016) to explain the variation in FAW effort. The complete scale, which covers use values directly related to profits and productivity as well as nonuse values such as paternalistic altruism, bequest value, existence value, option value, and pure nonuse values, is shown in Table A2. We measure *PA* using this scale. The three measurement items that measure this trait are listed in Table 2 with their mean scores and standard deviations.

[2]While there may be many more measures that define the welfare of animals at a farm, these were some of the measures that were easier to observe and account for in a quantitative survey. And since many FAW measures are unobserved or difficult to capture, we use these observed measures to define the unobserved farm animal welfare effort using a latent variable measurement model in our empirical strategy, acknowledging that these measures are perhaps a subset of the strategies that go into defining FAW effort.

Empirical framework

A unidimensional measure of FAW effort

Our focus is to capture the concept of FAW effort in a unidimensional scale from adoption of several FAW-improving strategies, thus informing us of producer's FAW effort. We use IRT models to develop this scale (Hambleton and Swaminathan 1985; Hand 1998). IRT models are widely used in the educational and other social science disciplines to evaluate programs (Chen and Thissen 1997; Abdul-Salam and Phimister 2017; Yount et al. 2019; Kellstedt et al. 2019). In our case, an IRT model implies that there exists a mathematical relationship between an unobserved latent trait (FAW effort) and the probability of adopting certain FAW-improving strategies. The IRT model considers the adoption of several FAW-improving measures as inputs into the model. The model output provides a unidimensional measure of the latent trait (FAW effort).

We use an IRT 1-parameter logistic model, which assumes that the probability of an individual adopting a FAW-improving measure follows the logistic distribution, defined by the difficulty parameter, b_j, associated with each measure, and a parameter θ, that describes the latent trait. The difficulty parameters define the underlying effort required for 50% of the respondents to adopt a specific measure. The following equation represents its mathematical form:

$$P\left(Y_{ij} = 1|\theta_i\right) = \frac{\exp\left(1.7a\left(\theta_i - bj\right)\right)}{1 + \exp\left(1.7a\left(\theta_i - bj\right)\right)} \tag{1}$$

where Y_{ij} is a binary response variable = 1, if farmer i adopts an input j, 0 otherwise. The parameter θ_i is the latent trait (FAW effort) for farmer i, b_j is the difficulty parameter that defines the underlying effort required for 50% of the respondents to adopt FAW-improving measure j, a is a constant called the discrimination parameter. It is assumed to be fixed and does not change between items in a 1-parameter IRT model and the number 1.7 is a scaling factor.[3]

Given that we have binary response items (i.e., 1 for adopting a FAW-improving measure and 0 otherwise), the model is most easily understood by examining the item characteristic curve (ICC) for each FAW-improvement measure. The ICC is a cumulative logistic function for the probability of adopting a measure on the Y-axis and a value "θ" (theta) on the X-axis. The parameter θ represents both the difficulty of adopting individual FAW-improving measure and the FAW effort level of farmers being surveyed. The point where the logit curve crosses the 0.5 value on the Y-axis is the point where a farmer with an effort level of θ would have a 50% probability of adopting a particular measure. Thus, the ICC represents the difficulty of the measure and maps it onto the latent trait. Measures with $\theta < 0$ are generally "easier" to adopt. As θ rises, the measures are increasingly "difficult" to adopt, and thus more effort is required to adopt a FAW-improving strategy. The IRT model therefore measures a unidimensional latent trait and also provides insight into which of the FAW-improving measures are more "difficult" to adopt.

Relationship between FAW effort and economic performance

We use a two-stage instrumental variable regression to avoid biased regression results due to omitted variables (such as farmer ability) and explain what drives FAW effort (and is uncorrelated with the profitability motive). We use the notion of use and nonuse values

[3]In IRT models, the scaling constant, 1.7, is used to scale the discrimination coefficient a from the logistic model to a normal metric (Savalei 2006).

related to FAW (as motivated by Hansson and Lagerkvist (2016), Lagerkvist et al. (2011) and McInerney 2004) to develop an instrumental variable. Indeed, farmer decision-making in relation to FAW adoption may be motivated not only by economic values derived from an increase in the productivity and profitability of the operation following the provision of FAW efforts (use values), but also by economic values derived from considerations beyond profit and productivity following the provision of FAW efforts (nonuse values) (McInerney 2004; Lagerkvist et al. 2011; Hansson and Lagerkvist 2015; Hansson and Lagerkvist 2016). The latter type of economic value can, for instance, be of pure nonuse value, bequest value, paternalistic altruism, option value, and existence value types. Pure nonuse value refers to farmer's interest in FAW, even when it is too costly to take 'better' care of their animals. Bequest value refers to farmer's desire to preserve farm animals (and their products) for future generations. Paternalistic altruism refers to farmers feeling proud that their animals' welfare is recognized by peers, the industry, and other stakeholders along the value chain. An option value relates to a farmer's desire to provide consumers with the option of choosing products developed with high FAW. Finally, existence value refers to farmers feeling satisfied about the well-being of their animals (Lagerkvist et al. 2011; Hansson and Lagerkvist 2016).[4]

We use one of the nonuse values (paternalistic altruism) as an instrumental variable because it is hypothesized to directly impact FAW effort, and only affects profit through FAW effort. The modeling approach is similar to a latent instrumental variable approach, which has been used in a wide variety of settings (Ebbes et al. 2009; Zhang et al. 2009; Rutz et al. 2012). Given that nonuse values, including the Paternalistic Altruism (*PA*), can be considered latent constructs, which cannot be measured directly, we use a Principal Factor Analysis (PFA) of the Likert scale rankings of measurement items associated with *PA*. This allows us to understand and pinpoint the important factors that underlie the latent construct. Table 2 provides the statements of the three measurement items associated with *PA*. PFA results in Table 3 suggest that Measurement Item 1 is the most important factor in explaining variance in *PA*.

From this PFA, we obtain the latent construct, *PA*, and include it in the first stage regression of *FAW* effort, as under.

$$FAW_i = \gamma_0 + \gamma_1 PA_i + \gamma_2 X_i + \mu_i \quad (2)$$

where FAW_i is the FAW effort score of farmer i based on the IRT model above. PA_i is the paternalistic altruism score of farmer i based on the PFA. The X_i are control variables such as herd size, managerial experience of the farmer, type of cattle operation, and proportion of income from the beef operation, and μ_i is the error term. In the next step, predicted values of *FAW* from Equation (2) are plugged in Equation (3) to estimate the relationship between *FAW* effort and economic performance:

$$y_i = \alpha_0 + \beta_1 \widehat{FAW}_i + \beta_2 X_i + e_i \quad (3)$$

where y_i is i) a contribution margins ratio, ii) a beef-related revenue per livestock unit (LU), and iii) a beef-related variable costs per LU for farm *i*. The variable is the predicted FAW effort score from Equation (2), X_i are the control variables as above, and e_i is the error term. The parameter β_1 captures the relationship between FAW effort and economic performance of a farm. Figure 1 provides a schematic representation of the empirical framework.

The identification assumptions for the instrumental variables are that the X_i are exogenous in both Equation (2) and (3), and $Cov\ (PA_i, e_i) = 0$, implying that *PA* is uncorre-

[4]The statements used to derive these values are provided in Table A2.

Table 3. Principal Factor Analysis for Paternalistic Altruism

	Eigen Value	Proportion
Measurement Item 1	1.181	1.275
Measurement Item 2	−0.033	−0.036
Measurement Item 3	−0.221	−0.238

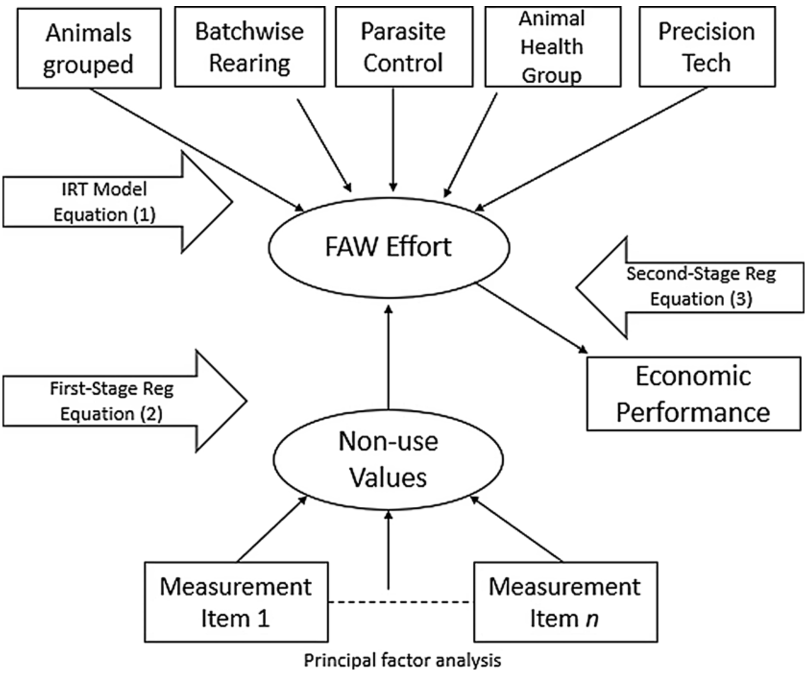

Figure 1. Schematic of the relationships between Nonuse Values, Farm Animal Welfare (FAW) Effort, and Economic Performance as estimated in the empirical framework.

lated with unobserved factors that affect economic performance, y_i, and is only related to economic outcomes through its effect on FAW_i. The plausibility of this assumption is discussed in section on *Robustness Checks*. Given the complexity of the model, the standard errors for estimates are bootstrapped with 1000 iterations.

Results and discussion

IRT model results

About 98% of the sample adopts at least one FAW-improving measure and 3% of the sample adopts all five. The discrimination parameter was estimated to be 0.88 and difficulty parameters ranged from −2.22 to 2.22, implying that the scale covers a wide range of FAW effort (Table 4). The ICC's for each of the five items are shown in Figure 2. The figure shows that the item *Animals Grouped* requires the least effort and is "easiest" to adopt

Table 4. Results from IRT Model

	Coefficients (Std Errors)	*P-Value*
Discrimination Parameter	0.885*** (0.185)	0.000
Difficulty Parameters		
Animals Grouped	−2.22*** (0.468)	0.000
Parasite Control	−0.69*** (0.255)	0.007
Animal Health Group	−0.45* (0.241)	0.058
Batchwise Rearing	1.36*** (0.358)	0.000
Precision Tech	2.22*** (0.448)	0.000

N = 115
Standard errors are reported in parentheses below the point estimates, and the associated p-value is reported in the adjacent column.
***, **, * denote statistical significance at 1, 5, and 10% level, respectively.

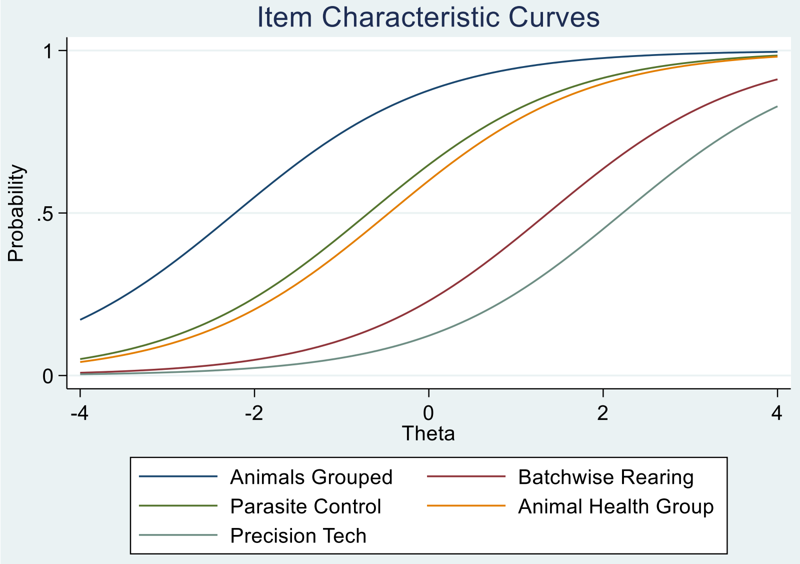

Figure 2. Item characteristic curves (ICC) from the IRT Model.

while *Precision Tech* is least adopted and is "harder" to adopt. *Batchwise Rearing*, *Parasite Control*, and joining an *Animal Health Group* fall between these two extremes.

The Test Information Function (TIF) and Test Characteristic Curve (TCC) are shown in Figure 3. The TIF and rising slope region of TCC show that our scale provides good

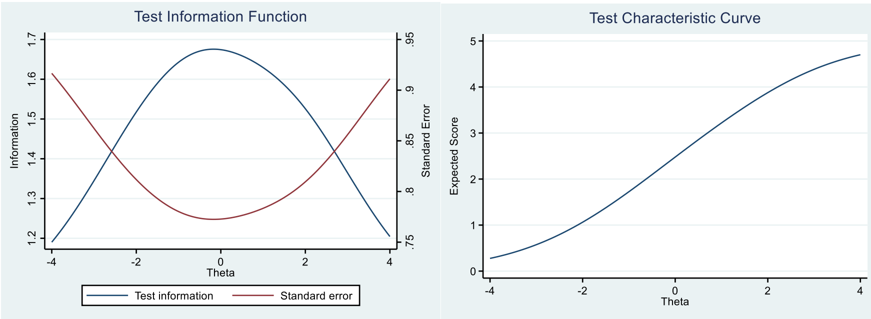

Figure 3. Test Information Function (TIF) and Test Characteristic Curve (TCC) from the IRT Model.

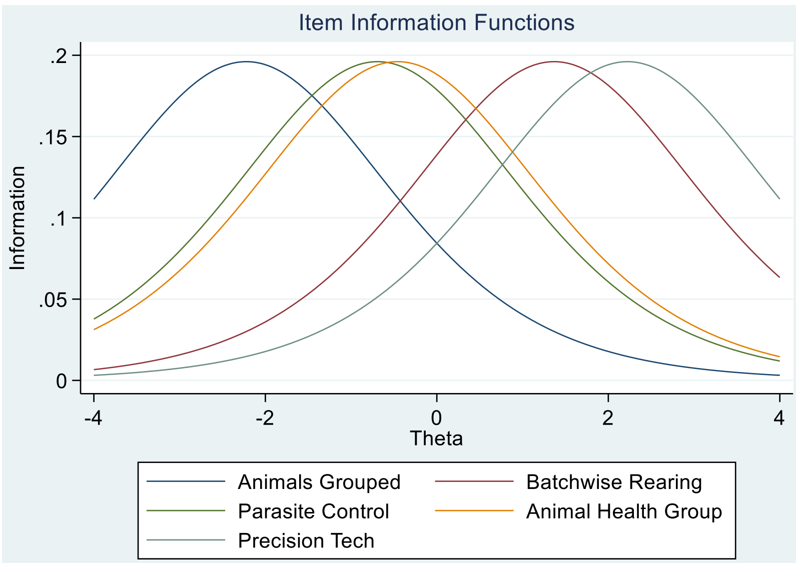

Figure 4. Item Information Functions for the Set of 5 FAW-Improving Management Strategies.

information for FAW effort level, θ, ranging from -2.5 to $+2.5$. These results suggest that our FAW measure is capturing a wide range (easy as well as difficult inputs) of FAW effort. Item information functions, which reflect the amount of information contributed by each item across the range of θ values, were created for all five items (Figure 4).

Collectively, the three plots (Figures 2, 3 and 4) indicate that the set of FAW-improving measures function reasonably well as a scale for measuring a producer's FAW effort. Furthermore, it performs well for values of $\theta < 0$ and $\theta > 0$ (given the peak of TIF is centered around 0), meaning it could successfully distinguish farmers with high effort from those with average or lower-than-average effort. A TIF peak around $\theta < 0$ means that the scale works better for individuals with lower-than-average latent score while a peak around $\theta > 0$ means that the scale captures the variability better for individuals with higher-than-average latent scores. A TIF that peaks around the values of $\theta \approx 0$ means that the scale can

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Table 5. Relationship between Paternalistic Altruism (*PA*) and FAW Scores – First Stage Regression

Dependent Variable: FAW Score	Coefficients (Std Error)	P-Values
PA	0.146*** (0.046)	0.002
Experience	−0.072 (0.085)	0.399
Herd Size	0.178*** (0.059)	0.004
Proportion of Income	0.065 (0.063)	0.298
Fattening	−0.228* (0.127)	0.072
Breeding	−0.463*** (0.131)	0.001
R-Squared	0.30	
F-Statistic	11.66	0.000

N = 115
Standard errors are reported in parentheses below the point estimates, and the associated p-value is reported in the adjacent column.
***, **, * denote statistical significance at 1, 5, and 10% level, respectively.

distinguish higher as well as lower than average individuals thus capturing the variability in latent score in a more reliable manner.

Explaining FAW effort

As introduced above, *PA* score is used as an independent variable in a two-stage regression to explain the variability in FAW effort. The results from the first-stage regression (Equation 2) are shown in Table 5. As expected, *PA* scores are positively and significantly related to FAW effort scores (p-value < 0.001). These findings illustrate that nonuse values (in this case, paternalistic altruism) are an important source of motivation to invest in FAW effort. The joint F-statistic for the first stage is 11.66, indicating that the instrumental variable bias will be negligible (Staiger and Stock 1997). Such findings can be used to improve agricultural policy and advice aimed at encouraging beef farmers to improve animal welfare. They also provide a basis for more realistic assumptions when developing economic models about producers' behavior. The predicted values of FAW effort from this regression are used in the second-stage regression to estimate the relationship between FAW effort and economic performance (in accordance with Equation 3).

Relationship between FAW effort and economic performance

Table 6 shows the relationship between FAW effort and farm economic outcomes, as estimated by Equation (3). Findings suggest that the relationship between *CMR* and FAW effort is not statistically significant at conventional levels of significance (Column 1, Table 6). Similarly, the effect of FAW effort on *Costs per LU* is not statistically significant

Table 6. Relationship between FAW Scores and Economic Outcomes – Second Stage Regressions

	CMR	*P-Value*	*Sales per LU*	*P-Value*	*Costs per LU*	*P-Value*
FAW Score	−12.85 (13.95)	0.357	−0.815** (0.399)	0.041	0.646 (0.461)	0.362
Experience	−0.90 (3.71)	0.823	0.170 (0.543)	0.870	−0.118 (0.375)	0.757
Herd Size	2.62*** (0.655)	0.000	1.05*** (0.353)	0.004	0.621** (0.305)	0.007
Proportion of Income	3.12 (6.35)	0.593	−0.376 (0.267)	0.333	0.212 (0.346)	0.537
Fattening	1.71 (3.20)	0.924	−0.605 (0.267)	0.148	0.176 (0.549)	0.817
Breeding	1.51 (7.50)	0.842	−1.38** (0.635)	0.033	0.600 (0.346)	0.582
R-Squared	0.15		0.21		0.20	

N = 115
***, **, * denote statistical significance at 1, 5, and 10% level, respectively.
Standard errors are reported in parentheses below the point estimates, and the associated p-value is reported in the next column.
Standard errors are bootstrapped using 1000 iterations.

at conventional levels of significance. However, greater FAW effort is associated with a statistically significant reduction in *Sales per LU* (p-value < 0.05).[5]

The channels through which FAW effort relates negatively to farm revenue may be two-fold. First, a farm may rate higher on the FAW effort score if the farmer is putting in the effort to rectify FAW problems and our estimate of negative effects on *Sales per LU* may capture the effect of bad animal health and welfare on the farm. In the section on *Robustness Checks*, we provide evidence that makes this channel to be the unlikely channel.

Second, we know that FAW effort, beyond statutory requirements, is a choice that depends on personal attributes and goals of the farmer. Indeed, in the previous section, we provided evidence that nonuse economic values (e.g., Paternalistic Altruism) play a vital role in explaining the variability of FAW effort, especially beyond the statutory requirements. Therefore, farms and farmers that are more focused on providing higher FAW may not be revenue maximizers in the traditional sense and may, for rational reasons, forego some of the revenue to maintain higher FAW through greater FAW efforts. For example, this reduction in *Sales per LU* may come from keeping lower rotation rates or providing a higher forage-to-concentrate feed ratio, which can enhance animal well-being but reduce the growth rates of animals (Ahmed et al. 2020), thus negatively affecting per unit revenue. These results are in line with the literature that suggests that producers may value other aspects of production beyond profits and productivity (like animal welfare) and rationally decide to accept some inefficiency on their farm to achieve multiple goals (Bogetoft and Hougaard 2003; Hansson et al. 2020; Adamie and Hansson 2022). Thus,

[5]Table A3 provides the estimates of the relationship between FAW effort and farm economic outcomes with simple OLS regressions for comparison. We also run the model after excluding the zero observations from the costs and sales and find similar results, suggesting that the zeroes in the dependent variables do not bias the regression estimates.

rational inefficiencies may explain the observed negative effect of FAW effort on *Sales per LU*.

Robustness checks

The first concern related to our estimation is regarding the channel through which a greater FAW effort may be related to the reduction in *Sales per LU*. Indeed, a farm may rate higher on the FAW effort score if the farmer is putting in the effort to rectify FAW problems and our estimate of reduction in sales may be due to bad animal health and welfare on the farm. We adopt two ways to rule out the possibility of this being the dominant channel of effect in our sample. First, if our FAW scores indeed captured the effort that went into correcting FAW problems on the farm and were associated with poor on-farm welfare, then we would expect to see a positive correlation between FAW score and animals culled due to disease. However, in Table A4, Column 1, we do not find a positive correlation between FAW score and number of animals culled due to disease, suggesting that higher FAW effort scores did not necessarily reflect poor on-farm welfare. Second, one of our FAW-improving measures, *Parasite Control*, may be adopted when the burden of parasites (e.g., gastrointestinal parasites, ticks) is higher on the farm (thus reflecting AW problems on the farm). We take this measure out of our IRT model and re-estimate our whole system of equations to make sure that our FAW effort score does not capture effort related to correcting bad on-farm animal welfare (Table A4, Columns 2, 3, and 4). We do not find any major changes in our results, again suggesting that the observed effect is not due to poor on-farm welfare. These results make rational inefficiencies to be a more plausible explanation of the observed results.

A second concern is related to the *Paternalistic Altruism* score; the exclusion variable used to identify the relationship between FAW effort and economic performance. Our identifying assumption is that *Paternalistic Altruism* is uncorrelated with unobserved factors that affect economic performance and is only related to economic outcomes through its effect on FAW effort. However, a potential concern could be that more profitable farms may rank themselves higher on the nonuse value scales as they may have greater cost cushion or higher incomes, thus introducing bidirectional causality within our regression framework. To test this, we regress *Paternalistic Altruism* on *CMR* and other control variables (in Table A5) and find that it is uncorrelated to *CMR*, thus alleviating the concern of reverse causality between the two variables. Furthermore, we do not find correlations between *Paternalistic Altruism* and other control variables, suggesting that it is uncorrelated with the unobserved error term, satisfying the exogeneity assumption of our instrument (Pei, Pischke and Schwandt 2019; Ahmed and Cowan 2021).

Third, similar to *Paternalistic Altruism*, other nonuse values such as *Existence Value* can also be used as an instrument since *Existence Value* is not directly related to economic performance and only related to economic outcomes through its impact on FAW inputs. Table A6 shows the results when *Existence Value*, instead of *Paternalistic Altruism*, is used as an instrumental variable. The results illustrate that the negative relationship between FAW effort and economic performance is robust even when an alternative nonuse construct is used as an instrumental variable.

Conclusions

Understanding the relationship between farm animal welfare effort taken by farmers and its consequences on economic performance of the farm is important given the recent debates surrounding the costs and benefits of farm animal welfare. This study examined the relationship between FAW effort taken on the farm and economic performance in beef production. We contribute to the literature by developing a composite FAW effort measure that encompasses multiple input-related dimensions of FAW effort into a unidimensional scale using the IRT model. Furthermore, we improve upon the existing correlational estimates between FAW effort and farm economic outcomes by using motivational constructs, such as paternalistic altruism, as instrumental variables that can explain the variation in FAW effort without being correlated with economic outcomes of the farm. This latent instrumental variable approach provides us a causal relationship between FAW effort and farm economic outcome.

We find that our scale of FAW effort reliably distinguishes the high-effort farmers from those with average or lower-than-average effort. Such a framework can be adapted to several production systems and species to characterize FAW effort of a farmer. We also find that nonuse values, such as paternalistic altruism or existence values, are an important source of motivation for farmers to invest in FAW. Lastly, we find that higher FAW effort scores have no effect on contribution margins and costs but are associated with lower farm sales. Indeed, production costs may not be the only channel through which higher FAW efforts affect profitability. Farmers, for rational reasons, may forego some of the revenue to maintain higher FAW through greater FAW efforts.

Our results have important implications for public and private policy makers as well as beef farmers. First, the relationship between motivational constructs and uptake of FAW practices suggests that psychological constructs related to FAW play an important role in the adoption of FAW practices. Thus, public policy should appeal to the personal and psychological attributes of farmers to better stimulate the uptake of FAW improvement measures. For the supply chain actors who collaborate with farmers, process and market their produce, targeted labeling policies that effectively differentiate high FAW products from mainstream products can be one of the strategies that can stimulate further uptake of FAW practices. Such a policy can incentivize FAW uptake among farmers who are not prepared to trade-off revenues for higher FAW, as well as to boost revenue for all types of farmers. Indeed, literature has found that consumers are willing to pay higher premiums for such food attributes, which in turn may boost farm revenue (Yang and Renwick 2019). In the absence of such an intervention, farmers are not likely to receive the full benefit of providing commodities with high FAW. Our results also provide some interesting insight to farmers. In particular, the finding that FAW efforts are not statistically significantly related with the contribution margin or with the costs per LU highlights that although FAW efforts may be costly, those costs seem to be offset by saving other costs (such as veterinary costs). Our results do not provide insight into the detailed mechanisms here, but it is likely that FAW efforts reduce the need for veterinary and husbandry costs.

Finally, it should be acknowledged that this study does not measure actual FAW on farm and future research is needed to understand in-depth the relationships between actual FAW and the farm economic performance. Future research will also have an important task to investigate the channels through which FAW effort negatively affects farm revenue and examine if greater FAW effort is indeed adopted under rational economic behavior.

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Appendix

Table A1. Data Description

Variable Names	Description
Beef Sales	Revenue generated by each farm through sale of beef cattle (in SEK).
Feed Costs	Farm-level costs associated with feeding beef cattle (in SEK).
Husbandry Costs	Farm-level costs associated with animal husbandry practices (in SEK).
Veterinary Costs	Farm-level costs associated with veterinary treatments and consultations (in SEK).
Contribution Margin Ratio (CMR)	Contribution Margin Ratio = [(Sales – Feed Costs – Veterinary Costs – Husbandry Costs)/ Sales] x 100
Sales per LU	Sales per Livestock Unit (LU) = Beef Sales/ Total LUs on farm.
Cost per LU	Cost per Livestock Unit (LU) = (Feed Costs + Veterinary Costs + Husbandry Costs)/ Total LUs on farm.
Herd Size (LU)	Number of livestock units (calves, cows, bulls etc.) on the farm.
Proportion of Income	The proportion of income generated through the beef enterprise.
Fattening Units	Indicator variable = 1 if farms specialize in fattening beef cattle, 0 otherwise.
Breeding Units	Indicator variable = 1 if farms specialize in breeding beef cattle, 0 otherwise.
Mixed Units	Indicator variable = 1 if farms are breeding as well as fattening beef cattle, 0 otherwise.
Experience	Number of years a farmer has managed a beef farm.
Animals Culled	Number of animals culled in the past 12 months.
Animals Grouped	Indicator variable = 1, if the farm practices separation of cattle groups (e.g., based on sex, age etc.), 0 otherwise.
Batchwise Rearing	Indicator variable = 1, if the farm rears young stock batchwise, 0 otherwise.
Parasite Control	Indicator variable = 1, if the farm treated/managed parasites (ticks/fleas) in the past 12 months, 0 otherwise.
Animal Health Group	Indicator variable = 1, if the farm is a part of any Animal Health group/ association, 0 otherwise.
Precision Tech	Indicator variable = 1, if the farm has adopted a precision technology to improve animal welfare, 0 otherwise.

Table A2. Use and Nonuse Values Related to Farm Animal Welfare
Please indicate to what extent the following motives are important to your cattle production decisions and operations (1 = Not important at all; 2 = Not important; 3 = neutral; 4 = somewhat important; 5 = extremely important)

1. To make sure that my beef cattle are kept in such a way that they can produce as much as possible	Use value
2. To make sure that the production of my beef cattle is at such a level that my business is as profitable as possible	Use value
3. To make sure that my beef cattle are kept in such a way that I can continue my business	Use value
4. To make sure that my beef cattle are healthy, so that I have time available to do other things	Use value
5. To make sure that my beef cattle are kept in such a way that my work environment is good	Use value
6. To make sure that my beef cattle are kept in such a way that my milk production is adjusted to current producer prices of milk	Use value
7. To make sure that my beef production is run in such a way that the current animal welfare law is satisfied, but not more.	Use value
8. To make sure that my beef cattle are kept in such a way that I can earn my living from my business	Use value
9. My interest in good handling of animals, even though it is currently too expensive to keep the animals in as good a way as I would like	Nonuse value/Pure nonuse value
10. For the business to make enough profit for me to further improve the way my beef cattle are kept	Nonuse value/Pure nonuse value
11. To feel happy knowing that my beef cattle are well-kept	Nonuse value/Existence value
12. To avoid feeling uncomfortable knowing that my beef cattle are not well-kept	Nonuse value/Existence value
13. Beef cattle have a right to be treated well	Nonuse value/Existence value
14. To make sure that my dairy production is ethical	Nonuse value/Existence value
15. To feel that I keep my beef production in the right way	Nonuse value/Existence value
16. To make sure that my beef cattle have free access to water and that they have a balanced fodder regime	Nonuse value/Existence value
17. To make sure that my beef cattle have good housing that offers shelter and comfortable places for resting	Nonuse value/Existence value
18. To make sure that disease, pain, and injury among my beef cattle are prevented and that diagnosis and treatment are quickly established if needed	Nonuse value/Existence value
19. To make sure that my beef cattle are able to practice their natural behaviors, for instance by offering enough space and the company of other beef cattle	Nonuse value/Existence value

(*Continued*)

Table A2. (*Continued*)

20. To prevent my beef cattle feeling fear or in other ways suffering mentally	Nonuse value/Existence value
21. To make sure my beef cattle feel well even when this requires unprofitable actions	Nonuse value/Pure nonuse value
22. To contribute to future generations also being able to experience beef cattle outdoors in their natural environment	Nonuse value/bequest value
23. To contribute to beef cattle in Sweden being so well kept that Swedish beef production can continue	Nonuse value/bequest value
24. To contribute to giving consumers the choice to purchase food products that have been produced under good animal husbandry, if they would like to do that	Nonuse value/option value
25. To make sure that consumers will continue to demand my production in the long run	Nonuse value/ paternalistic altruism
26. To feel proud that the way I keep my animals is acknowledged by the industry, market, or consumers	Nonuse value/ paternalistic altruism
27. To contribute to consumers being offered high-quality food products	Nonuse value/ paternalistic altruism

Table A3. Relationships between FAW Scores and Economic Performance – OLS Regressions (without IV)

	CMR	*P-Value*	*Sales per LU*	*P-Value*	*Costs per LU*	*P-Value*
FAW Score	−1.04 (1.133)	0.325	−0.72** (0.301)	0.044	0.676 (0.456)	0.142
Experience	−0.018 (1.15)	0.851	0.219 (0.336)	0.691	−0.019 (0.365)	0.960
Herd Size	2.60*** (0.664)	0.000	0.979*** (0.237)	0.005	0.61** (0.257)	0.047
Proportion of Income	0.417 (0.823)	0.565	−0.269 (0.320)	0.229	0.279 (0.357)	0.350
Fattening	−0.934 (1.251)	0.474	−0.510 (0.478)	0.177	0.005 (0.518)	0.995
Breeding	−1.579 (1.595)	0.355	−1.29** (0.542)	0.045	0.541 (0.587)	0.335
R-Squared	0.10		0.20		0.18	

N = 115
Standard errors are reported in the parentheses below the point estimates and the associated p-value is reported in the next column.
***, **, * denote statistical significance at 1, 5 and 10% level, respectively.
Standard errors are clustered at the farm-level.

Table A4. Relationship between FAW Scores, Animals Culled, and Economic Performance

	Animals Culled	*P-Value*	*CMR*	*P-Value*	*Sales per LU*	*P-Value*	*Costs per LU*	*P-Value*
FAW Score	−0.024 (0.082)	0.764	−12.80 (13.52)	0.344	−0.741** (0.301)	0.041	0.517 (1.67)	0.757
Experience	−0.125 (0.079)	0.117	0.220 (3.57)	0.911	0.254 (0.550)	0.693	−0.146 (0.360)	0.680
Herd Size	1.34*** (0.063)	0.000	3.17*** (0.799)	0.005	0.981*** (0.340)	0.004	0.651* (0.347)	0.061
Proportion of Income	0.044 (0.062)	0.477	2.89 (6.17)	0.637	−0.566 (0.361)	0.212	0.246 (0.335)	0.456
Fattening	0.185 (0.113)	0.104	1.89 (9.10)	0.846	−0.800 (0.682)	0.183	0.156 (0.538)	0.834
Breeding	0.296*** (0.063)	0.006	−1.749 (1.43)	0.923	−1.13* (0.588)	0.054	0.542 (0.521)	0.344
Pseudo R-Square	0.58		–		–		–	
R-Squared	–		0.10		0.21		0.20	

N = 115
Standard errors are reported in the parentheses below the point estimates, and the associated p-value is reported in the next column.
***, **, * denote statistical significance at 1, 5, and 10% level, respectively.
Column 1 shows regression estimates from Poisson regression.
For regression estimates in Columns 2, 3, and 4, standard errors are bootstrapped using 1000 iterations.

Table A5. Correlates of Paternalistic Altruism

	Coefficients (Std Errors)	P-Value
CMR	−0.002 (0.002)	0.408
Experience	0.161 (0.253)	0.527
Herd Size	0.161 (0.128)	0.212
Proportion of Income	0.005 (0.121)	0.967
Fattening	0.212 (0.229)	0.447
Breeding	0.146 (0.293)	0.620

N = 115
Standard errors are reported in parentheses below the point estimates, and the associated p-value is reported in the adjacent column.

Table A6. Relationship between FAW Scores and Economic Outcomes – Second Stage 2SLS Regression with *Existence Value* as Instrument

	CMR	*P-Value*	*Sales per LU*	*P-Value*	*Costs per LU*	*P-Value*
FAW Score	−6.12 (5.70)	0.183	−0.778** (0.384)	0.043	1.401 (1.74)	0.418
Experience	0.264 (0.913)	0.841	0.230 (0.752)	0.717	−0.121 (0.374)	0.650
Herd Size	2.77*** (0.708)	0.000	1.07*** (0.364)	0.003	0.580* (0.328)	0.069
Proportion of Income	0.542 (0.708)	0.195	−0.338 (0.276)	0.205	0.181 (0.339)	0.680
Fattening	−0.829 (1.395)	0.357	−0.547 (0.418)	0.191	0.043 (0.752)	0.891
Breeding	−2.337 (1.562)	0.128	−1.47** (0.651)	0.023	0.756 (0.796)	0.320
R-Squared	0.13		0.21		0.20	

N = 115
Standard errors are reported in parentheses below the point estimates, and the associated p-value is reported in the next column.
***, **, * denote statistical significance at 1, 5, and 10% level, respectively.
Standard errors are bootstrapped using 1000 iterations.

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